Recommendations of Target Freshwater Inflows for the Trinity-San Jacinto Estuary Based on Analysis of Long-Term Fisheries Survey Data

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1975-1987   Research Scientist, University of Texas, studying the biological effects of pollutants on marine organisms, laboratory cultivation of marine invertebrates for research purposes, and biology of the early life stages of red drum in the laboratory.

1987 - present   Coastal Ecologist, Texas Parks and Wildlife Department (TPWD) at Austin, assisting the State Bays and Estuaries Program in analyzing TPWD coastal fishery data to determine freshwater inflow needs for major Texas bays and estuaries. He has published 27 papers in reviewed professional journals and a dozen published agency project reports.

FRESHWATER INFLOW RECOMMENDATION
FOR THE TRINITY - SAN JACINTO ESTUARY
BASED ON ANALYSIS OF LONG-TERM FISHERIES SURVEY DATA

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INTRODUCTION

Methods for determination of the quantity and quality of freshwater inflows (FWI) needed to maintain our coastal margins have been developed by the State Bays and Estuaries Research Program [consisting of the Texas Water Development Board (TWDB) and Texas Parks & Wildlife Department (TPWD)]. These determinations rely on the Estuarine Mathematical Programming Model (TXEMP) and hydrodynamic model (TXBLEND) to estimate minimum FWI (termed the MinQ flow) and maximum harvest FWI (termed MaxH flow) for each estuary (Figure 1). TPWD subsequently analyses fisheries survey data from its Coastal Fisheries Resource Monitoring Database to validate results of these computer simulations. Empirical assessments are performed to 1) evaluate the biotic suitability of the seasonal salinity zones at MinQ and MaxH and 2) correlate historical abundance of estuarine fisheries with observed, seasonal salinity regimes (as a proxy for FWI). This comparison of theoretical modeling results with TPWD fisheries survey data produces a reasonable FWI recommendation that maintains the "biological health and productivity" of each estuary.

REVIEW OF TWDB/TPWD MODELING RESULTS

When applied to the Trinity-San Jacinto Estuary, the optimization model (TXEMP) produces a range of solutions that simultaneously predict seasonal (monthly) inflows to the Estuary, and the corresponding estuarine fishery harvests, which satisfy model constraints (Fig. 1, top). These monthly inflows are constrained between the 10th and 50th percentile historical inflows (Fig. 1, bottom). Output from TXEMP serves as input to the two dimensional, finite element hydrodynamic circulation model (TXBLEND) which simulates patterns of salinity distributions and bay circulation.

Minimum and maximum annual inflow (MinQ & MaxQ) were computed to be 4.16 and 6.18 million acre-ft/year respectively. The model predicted that maximum fisheries harvest (MaxH) would occur at 5.22 million acre-ft/yr. Figure 1 (bottom) compares the monthly inflow distributions for MinQ and MaxH cases to two historical cases: the median (50th percentile) and 10th percentile flows. Despite

a large difference between MinQ and MaxH flows (*ca* 25 %), the difference in total fisheries harvest between the two cases (10.7 vs. 11.7 million pounds for MinQ vs. MaxH, respectively) is small (*ca* 9 %), with MaxH flow producing slightly higher harvests of blue crab, oysters, red drum, black drum and white shrimp.

OBSERVED BIOLOGICAL RESPONSES TO HISTORICAL FRESHWATER INFLOWS
Effects of MinQ vs. MaxH Salinity Regimes Predicted from Modeling

Geographic Information System (GIS) techniques are used to compare salinity maps from the hydrodynamic model under optimized MaxH or MinQ inflows. These maps are generated by contouring the salinities from each model run using Arc/Info GIS programs. Salinity change analysis was performed by overlaying MinQ and MaxH salinity maps for each month, thus producing salinity difference maps between MaxH and MinQ. Locations of wetlands and oyster reefs were overlaid onto these monthly plots to determine impacts. The distribution of sensitive marsh wetlands in the Trinity Bay Delta region (552 ha of brackish marsh and 1,867 ha of intermediate marsh) were considered critical to this evaluation. There were only small salinity differences (< 1.0 ppt) between MaxH and MinQ cases from January until April. In June, the largest salinity differences between the MaxH and MinQ cases (up to 4 ppt) were evident in the Middle and Lower parts of the Bay.

Time-series analyses were performed on the salinity data from the TXBLEND model at selected sites in the Bay to determine if salinity constraints are exceeded. Because of the commercial importance of oyster production at locations in the middle of Galveston Bay, the annual salinity time-series was also used to generate predictions of FWI effects on oysters and the oyster disease (Perkinsus marinus). Little difference in oyster production due to salinity was predicted between the MaxH and MinQ cases. However, owing to Perkinsus sensitivity to low salinities, the prevalence and duration of the disease was less in the MaxH case. This small difference in disease prevalence could, in turn, result in large differences in annual oyster harvest in Galveston Bay.

Spatial Analysis of Preferred Salinity Zones for Target Fauna

Table 1 lists the characteristics of the TPWD Coastal Fisheries database, as well as analytical methods used in deriving preferred salinity zones. Data from 1982 to 1993 were used to derive

Table 1. Fisheries Data Source and Methodology used for deriving Preferred Salinity Zones.

TPWD COASTAL FISHERIES DATABASE
        Long-term Sampling Program (since late 70's)
        20 Trawl Samples per Month in each Estuary
        Hydrographic Parameters Collected Simultaneously

TARGET SPECIES ANALYZED

White Shrimp   Blue Crab
Brown Shrimp   Atlantic Croaker
Gulf Menhaden   Bay Anchovy
Pinfish

ANALYSIS TECHNIQUES

Spatial Correlation (Geographic Information System)
Contouring (Kriging)
Statistics (Nonparametric, ANOVA)

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spatial correlations between salinity and the relative catch (CPUE) of seven target species. GIS spatial overlay analyses, developed for trawl catch rates and salinity zones, helped to demonstrate the preferred salinity zones for white and brown shrimp, blue crab, Gulf menhaden, Atlantic croaker, bay anchovy, and pinfish. This procedure allowed determination of the actual preferred salinity zone from abundance of young animals caught in otter trawls and the salinity distribution within the Estuary (see blue crab example in Fig. 2). From these Arc/Info GIS plots, two critical data values for each species were calculated: 1) the percent abundance of animals in bay salinity zones, and 2) the percent of bay area occupied by that salinity zone. Correlations between salinity zone and relative abundance allowed salinity preference zones (where peak density occurred) to be derived for each species.

Statistical analyses confirm that both shellfish (brown shrimp, white shrimp and blue crab) and finfish (Gulf menhaden, bay anchovy and pinfish) vary in their distribution according to unique salinity preferences (Table 2). Six species showed a significant preference for a particular salinity regime, defined as the optimum zone where density is highest. Three species (white shrimp, blue crab, and Gulf menhaden) have salinity preference zones for brackish to low mesohaline regions of the Bay. Two species (including brown shrimp and bay anchovy) show preference zones for mid to upper mesohaline regions, while the pinfish has a preference for the high salinity regions of the bay. Atlantic croaker was not associated with discrete salinity zones.

Comparison of Observed Sample Salinity Zones vs. MinQ or MaxH Predicted Zones

An additional comparison of observed to predicted salinity preference zones was then conducted to establish whether MinQ and/or MaxH inflows produce satisfactory salinity gradients in the bay to maintain observed rates of fisheries production. Salinity contour maps of the observed preferred salinity zones for each species are compared to salinity maps created by contouring the salinities under MinQ and MaxH flows for the same time period. An example of this analysis is shown in Fig. 3 for the blue crab. These GIS plots are used to calculate percent of bay area occupied by the various salinity zone areas for the two model cases, MinQ or MaxH, and the observed sampling data

(Table 2). Based on relative comparison of areal percentages, the suitability of predicted flows for producing the desired, preferred salinities can be evaluated.

INFLOW RECOMMENDATION SUMMARY

TPWD staff recommends MaxH (5.22 million acre-ft/yr) inflow as the lowest FWI target value which generally fulfills the biological needs of the Galveston Estuary on a seasonal basis. TPWD prefers the conservative value of MaxH which provides conditions closer to the salinity preferences of the target species and protects the oyster fishery from disease (P. marinus). The distribution of MaxH flows approximating the historical monthly median pattern provides the most adequate salinity conditions during the critical spring months of May and June. Dryer conditions during summer months (July and August) may be expected naturally and can be tolerated if the estuary is provided with adequate inflows earlier in the year.

Table 2. Preferred Salinity Zone Area under Three Inflow Regimes

Target Species	Preferred Salinity Zone (ppt)	Observed Sample Case (% Bay Area)	Min Q Case (% Bay Area)	Max H Case (% Bay Area)
White Shrimp	10 - 15	32.2	21.9	23.7
Brown Shrimp	10 - 20	44.3	37.4	30.4
Blue Crab	0 - 15	60.8	48.1	60.5
Gulf Menhaden	10 - 15	37.0	21.3	22.5
Atlantic Croaker	None	--	--	--
Bay Anchovy	10 - 20	50.1	39.3	35.8
Pinfish	20 - 25	26.8	13.8	15.7

Figure 1

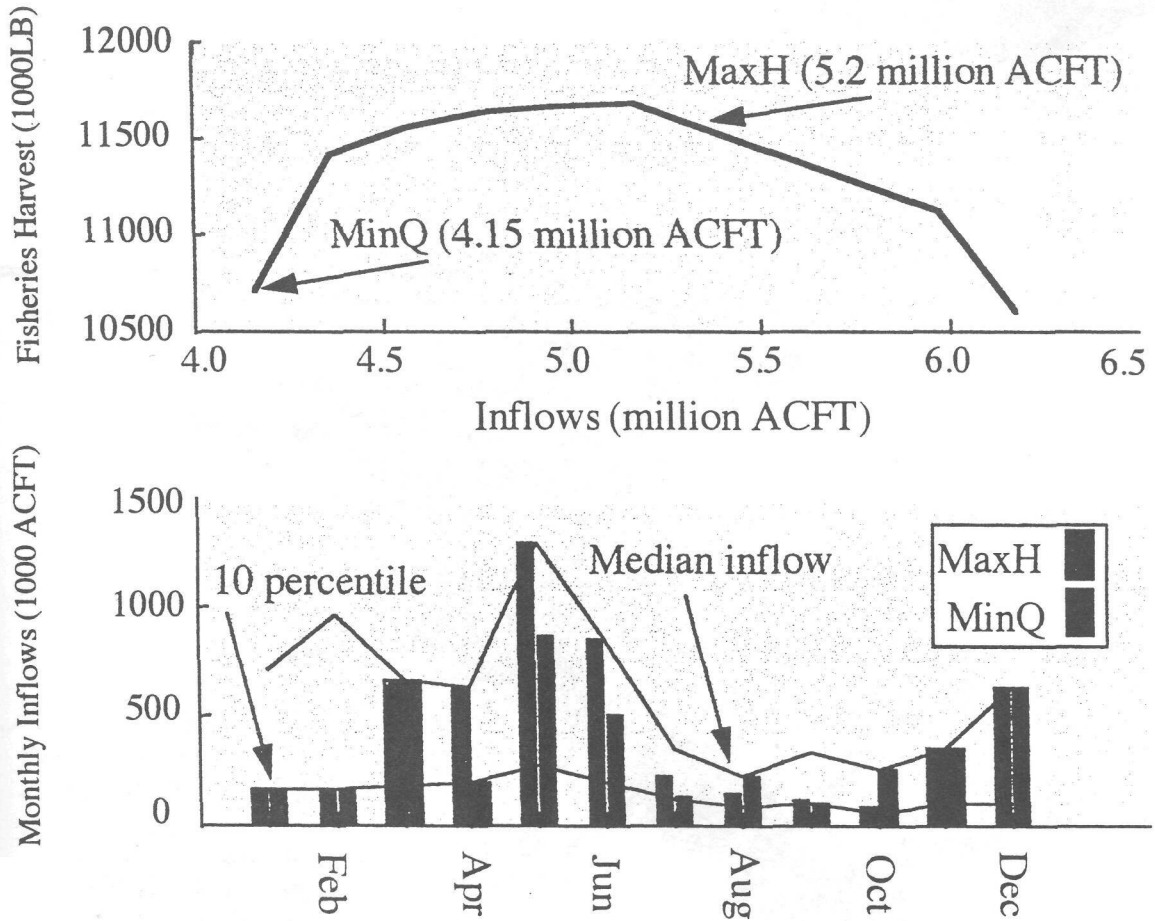## MaxH and MinQ Inflow Cases: Performance Curve and Monthly Inflows

Figure 2 — Spatial Distribution of Blue Crab in the Galveston Bay System
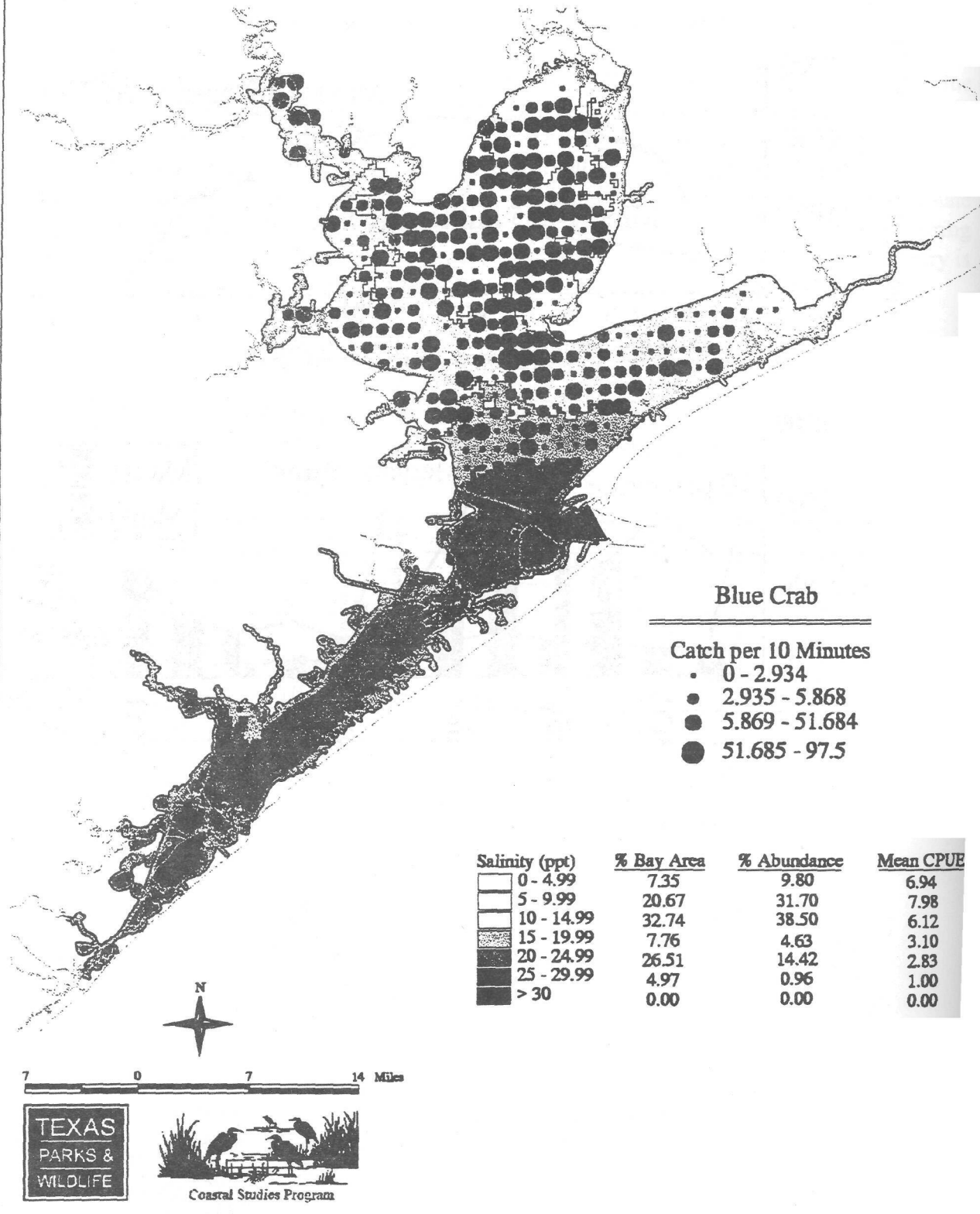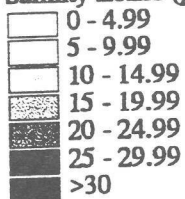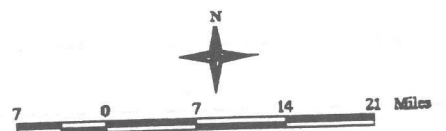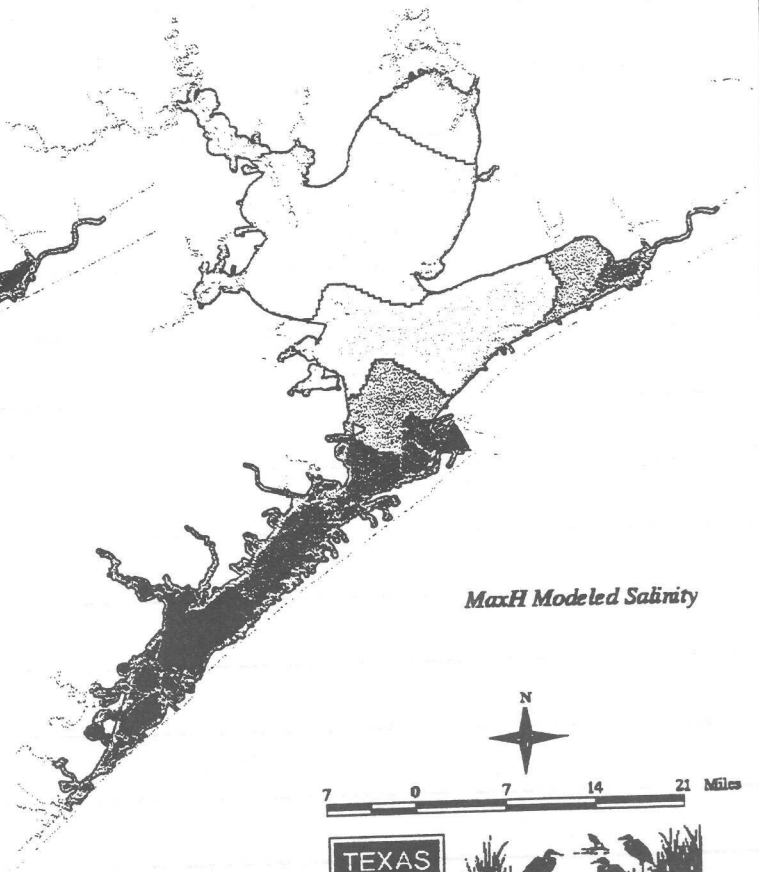
March - August
1982 - 1993

Blue Crab

Catch per 10 Minutes
- 0 - 2.934
- 2.935 - 5.868
- 5.869 - 51.684
- 51.685 - 97.5

Salinity (ppt)	% Bay Area	% Abundance	Mean CPUE
0 - 4.99	7.35	9.80	6.94
5 - 9.99	20.67	31.70	7.98
10 - 14.99	32.74	38.50	6.12
15 - 19.99	7.76	4.63	3.10
20 - 24.99	26.51	14.42	2.83
25 - 29.99	4.97	0.96	1.00
> 30	0.00	0.00	0.00

N

7   0   7   14 Miles
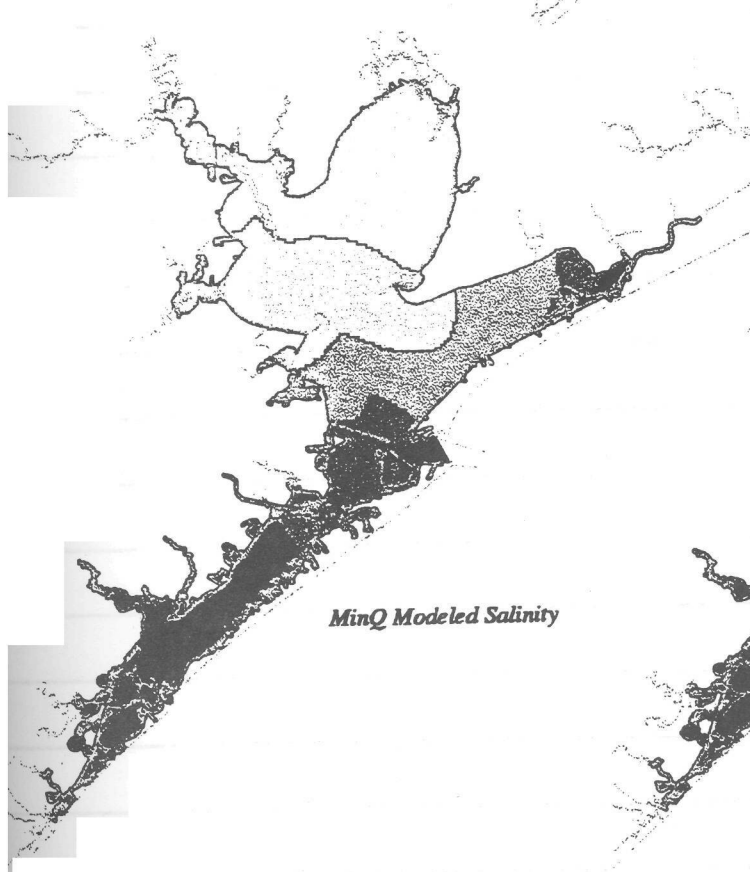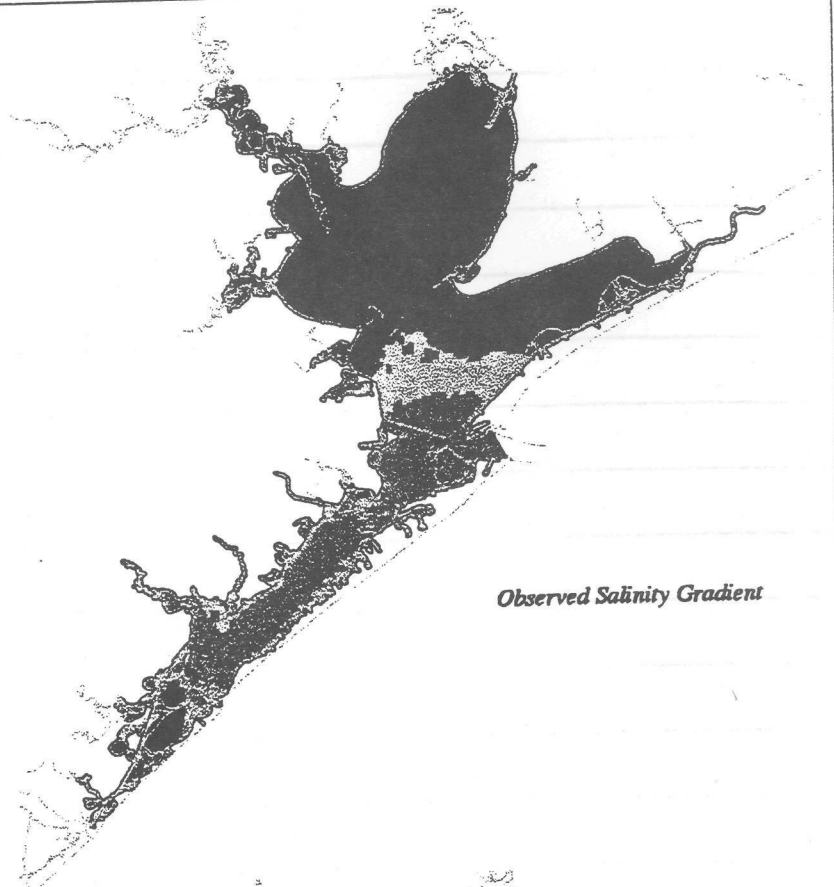
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Figure 3

Blue Crab
Observed Salinity Gradient
vs.
MinQ and MaxH Salinity Patterns
March - August
1982 - 1993

Salinity Zones (ppt)
- 0 - 4.99
- 5 - 9.99
- 10 - 14.99
- 15 - 19.99
- 20 - 24.99
- 25 - 29.99
- >30

Preferred Salinity Zones
(0 - 14.99)

Observed Salinity Gradient

MinQ Modeled Salinity

MaxH Modeled Salinity

N

7   0   7   14   21 Miles

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